Case Voltage Conditioning Tool

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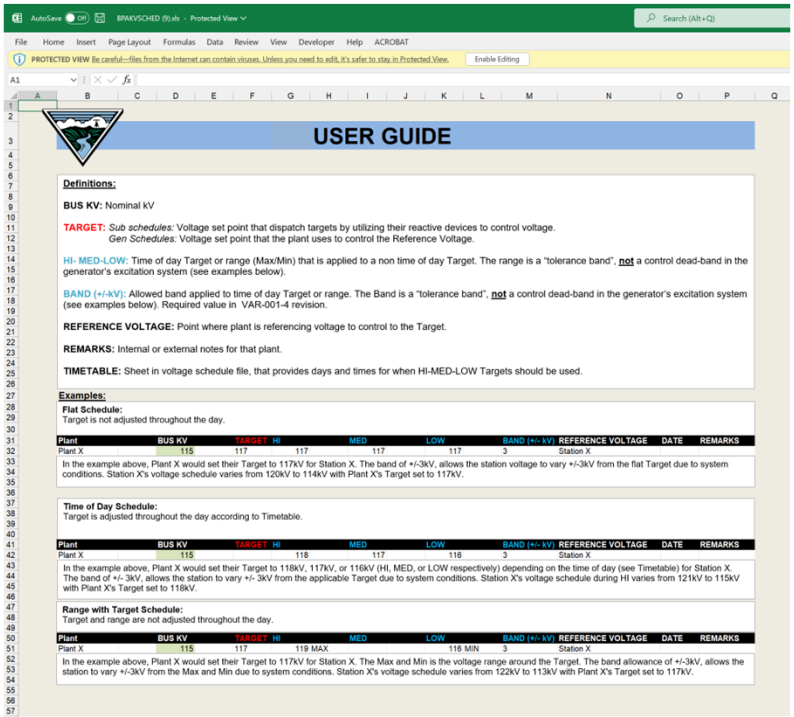
WECC User's Group Meeting
October 2022

PowerWorld Corporation

Case Voltage Conditioning

- Work done with BPA based on their public substation and generator voltage schedules
- https://transmission.bpa.gov/Business/Operations/Misc/default.aspx
- It's a spreadsheet with Voltage schedules by
  - Substation
  - Nominal KV



USER GUIDE

Definitions:

BUS KV: Nominal kV

TARGET: *Sub schedules:* Voltage set point that dispatch targets by utilizing their reactive devices to control voltage.
Gen Schedules: Voltage set point that the plant uses to control the Reference Voltage.

HI- MED-LOW: Time of day Target or range (Max/Min) that is applied to a non time of day Target. The range is a "tolerance band", **not** a control dead-band in the generator's excitation system (see examples below).

BAND (+/-kV): Allowed band applied to time of day Target or range. The Band is a "tolerance band", **not** a control dead-band in the generator's excitation system (see examples below). Required value in VAR-001-4 revision.

REFERENCE VOLTAGE: Point where plant is referencing voltage to control to the Target.

REMARKS: Internal or external notes for that plant.

TIMETABLE: Sheet in voltage schedule file, that provides days and times for when HI-MED-LOW Targets should be used.

Examples:

Flat Schedule:
Target is not adjusted throughout the day.

Plant	BUS KV	TARGET: HI	MED	LOW	BAND (+/- kV)	REFERENCE VOLTAGE	DATE	REMARKS
Plant X	115	117	117	117	3	Station X		

In the example above, Plant X would set their Target to 117kV for Station X. The band of +/-3kV, allows the station voltage to vary +/-3kV from the flat Target due to system conditions. Station X's voltage schedule varies from 120kV to 114kV with Plant X's Target set to 117kV.

Time of Day Schedule:
Target is adjusted throughout the day according to Timetable.

Plant	BUS KV	TARGET: HI	MED	LOW	BAND (+/- kV)	REFERENCE VOLTAGE	DATE	REMARKS
Plant X	115	118	117	116	3	Station X		

In the example above, Plant X would set their Target to 118kV, 117kV, or 116kV (HI, MED, or LOW respectively) depending on the time of day (see Timetable) for Station X. The band of +/- 3kV, allows the station to vary +/- 3kV from the applicable Target due to system conditions. Station X's voltage schedule during HI varies from 121kV to 115kV with Plant X's Target set to 118kV.

Range with Target Schedule:
Target and range are not adjusted throughout the day.

Plant	BUS KV	TARGET: HI	MED	LOW	BAND (+/- kV)	REFERENCE VOLTAGE	DATE	REMARKS
Plant X	115	117	119 MAX	116 MIN	3	Station X		

In the example above, Plant X would set their Target to 117kV for Station X. The Max and Min is the voltage range around the Target. The band allowance of +/-3kV, allows the station to vary +/-3kV from the Max and Min due to system conditions. Station X's voltage schedule varies from 122kV to 113kV with Plant X's Target set to 117kV.

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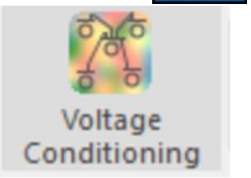
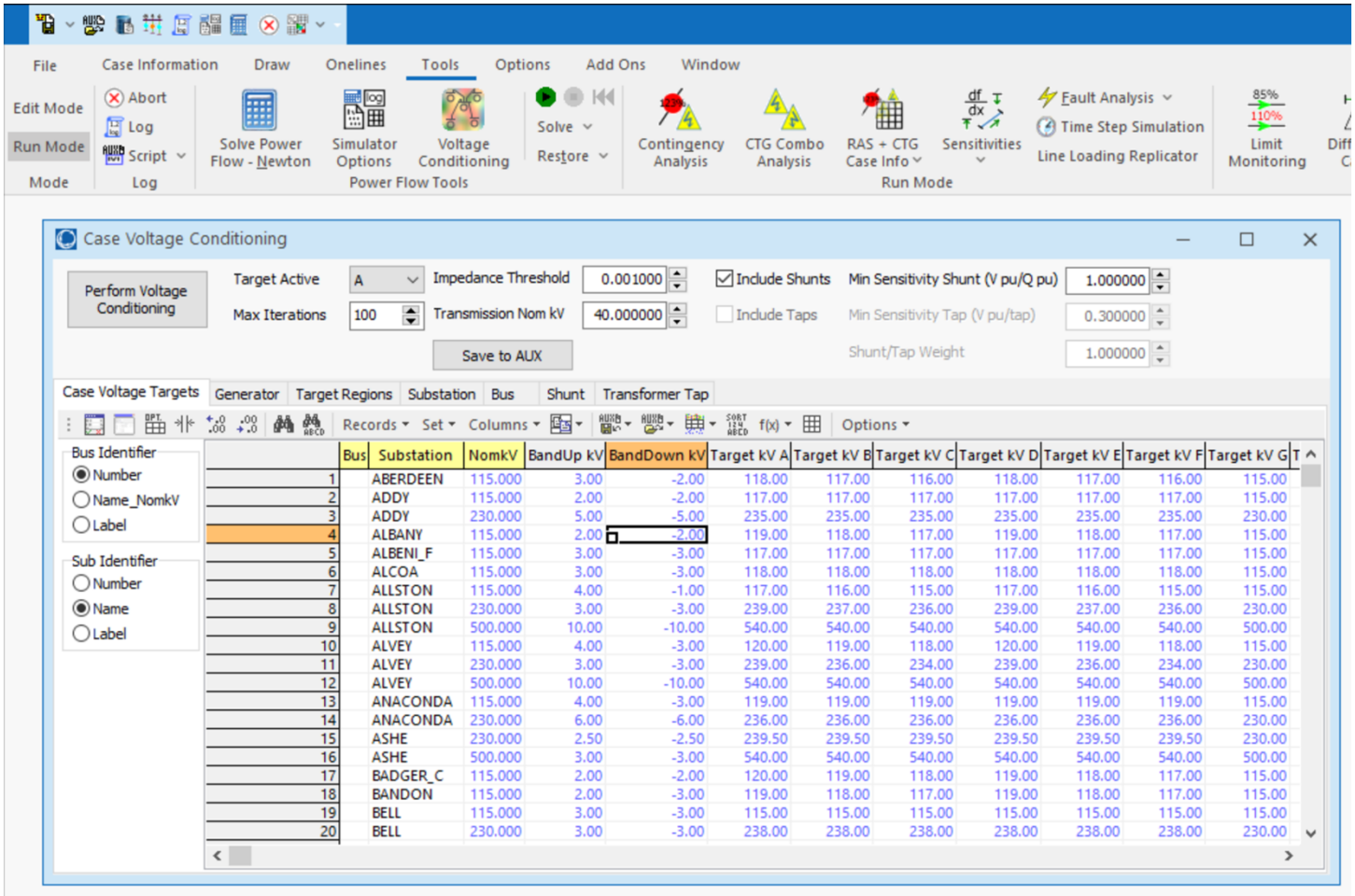
PowerWorld New Object: CaseVoltageTarget

- Available under Tools, Voltage Conditioning





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CaseVoltageTarget Objects

Field	Type	Description
Bus	string (KEY field)	A bus to which this desired voltage target applies. The identifiers used are determined by the BusIdentifier field of the **CaseVoltageTargetTool** object. If this is specified, then the Substation is ignored.
Substation	string (KEY field)	Substation to which this desired voltage target applies (used only if Bus is empty). The identifiers used are determined by the SubIdentifier field of the **CaseVoltageTargetTool** object
NomkV	single float (KEY field)	Nominal kV of the buses inside a substation that should be considered. If the Bus field is specified however, this will return the nominal kV of the Bus and the value will not be enterable.
Description	string	An extra string for the user to describe this entry.
BandUpkV BandUpPU	single float	Voltage deviation in kV or per unit **above** the voltage target that is considered acceptable (*must be a positive value*). Internally a value is stored in per unit, so editing using the kV values will set the per unit value equal to the entered value divided by the NomkV field.
BandDownkV BandDownPU	single float	Voltage deviation in kV or per unit **below** the voltage target that is considered acceptable (*must be a negative value*). Internally a value is stored in per unit, so editing using the kV values will set the per unit value equal to the entered value divided by the NomkV field.
ErrorkV ErrorPU	single float	This fields looks at all buses that are using this CaseVoltageTarget, so for Subsation/NomkV type of Target it may be multiple buses. Over all these buses, this returns the largest magnitude deviation from the voltage band. Buses with voltages inside the band are treated as having an error of 0.0000.
TargetkVA ... TargetkVH TargetPUA ... TargetPUH	single float	Specify a voltage target in either kV or per unit to use depending on the TargetActive being “A”, “B”, … , “H” Internally the values are stored in per unit, so editing using the kV values will set the per unit value equal to the entered value divided by the NomkV field.

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TargetPUA…TargetPUH TargetkVA…TargetkVH

- These are 8 different voltage targets
  - Specify in either PU or kV for user-convenience
    - TargetPUA and TargetkVA are stored as one value in PowerWorld and just displayed to you differently
  - A…H are intended to represent different operating conditions.
    - For BPA this will be a combination seasonal variation and load variation, for example
      - A = High load times, Summer
      - B = Medium load times, Summer
      - C = Low load times, Summer
      - D = High load, Winter
      - E = Medium load, Winter
      - F = Low load, Winter
      - G, H aren't used yet

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CaseVoltageTargetRegion

- New object with 2 fields
  - Name
    - Name of the object for a key field
  - TargetActive: A, B, C, D, E, F, G or H
    - This is which of the targets to use
- For BPA, these target regions are 2 things:
  - MST : Mountain Standard Time
  - PST : Pacific Standard Time
  - In their operations the time-of-day translates to High, Medium and Low load profiles differently in these time zones
    - But really a TargetRegion could be any group representing buses whose transition between different TargetActive values at the same times
- PowerWorld Cruncher will have a tool to populate this TargetActive appropriately as the system varies with time

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Assignment of Buses to CaseVoltageTargetRegion

- New field available for Bus and Substation
  - Bus.CaseVoltageTargetRegion
  - Substation.CaseVoltageTargetRegion

- If a bus has a CaseVoltageTargetRegion it uses it, otherwise it looks at the Substation CaseVoltageTargetRegion

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Choosing the appropriate Regulated Bus

- Data for voltage schedules is provided by SUBSTATION/NomkV
  - Would be easier to ask our user to map this to a particular bus, but in full topology models this gets complicated
    - User can specify by BUS of course as that's easier for us!
  - The input data that exists is Substation/Nominal kV
- Another Data issue
  - EMS cases often have generator's configured to regulate the 0.300 – 40 kV low-voltage bus
  - Voltage schedule data is at transmission level 115 kV up to 500 kV
    - In practice generator schedules are guidance to generator operators. There isn't a control system doing this, but a human operator

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Choose Regulated Bus: ConditioningRegBus

- Generator Field: ConditioningRegBus
  - This new field does a search
  - Breath-First search looking outward for a bus with a nominal voltage greater than equal to a user-specified value
    - CaseVoltageTargetTool.TransmissionNomkV
      - This is the nominal voltage above which this tool considers things to be “transmission
  - After reaching this first “transmission bus”, we then search outwards across any near-zero impedance branches for a transmission line or transformer
    - We skip over breakers, disconnects, etc…

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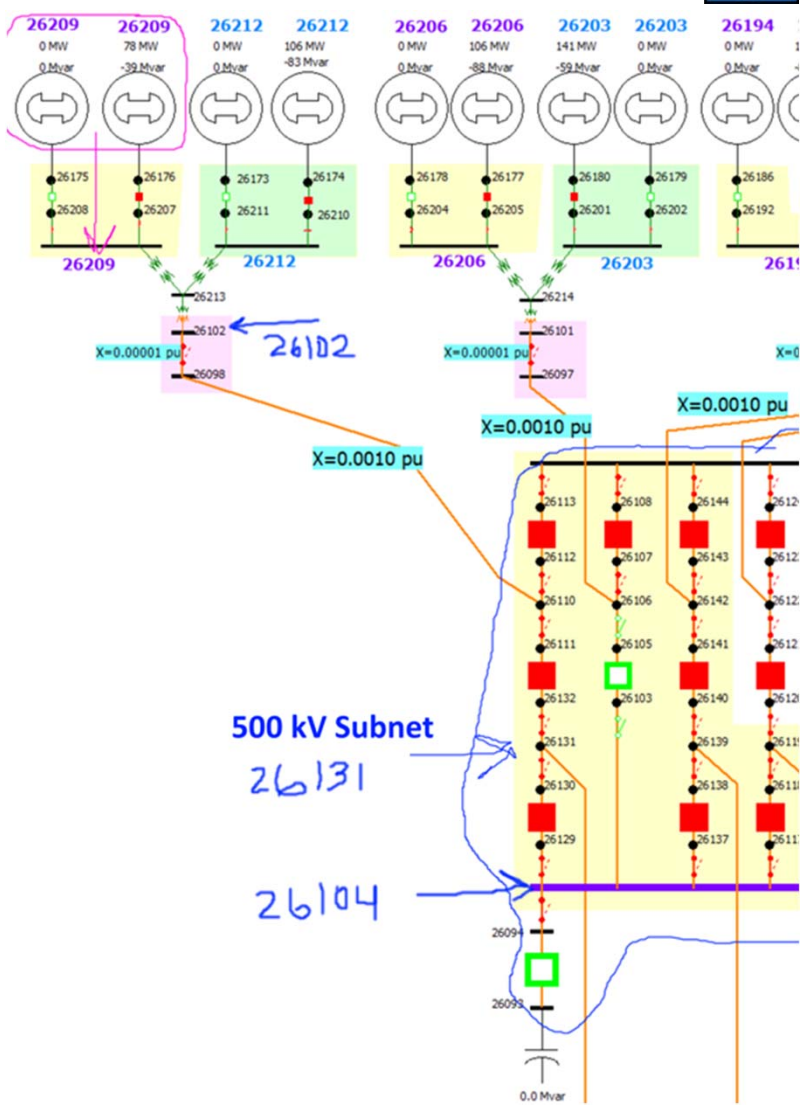
Example ConditioningRegBus

- Start 26209 → Breadth first search transmission kV
  - 26102 is first 500kV bus
- Search over low impedances
  - 26131 is first bus connected to a transmission line
- Finally choose the primany node of this SuperBus
  - 26104 becomes the ConditioningRegBus



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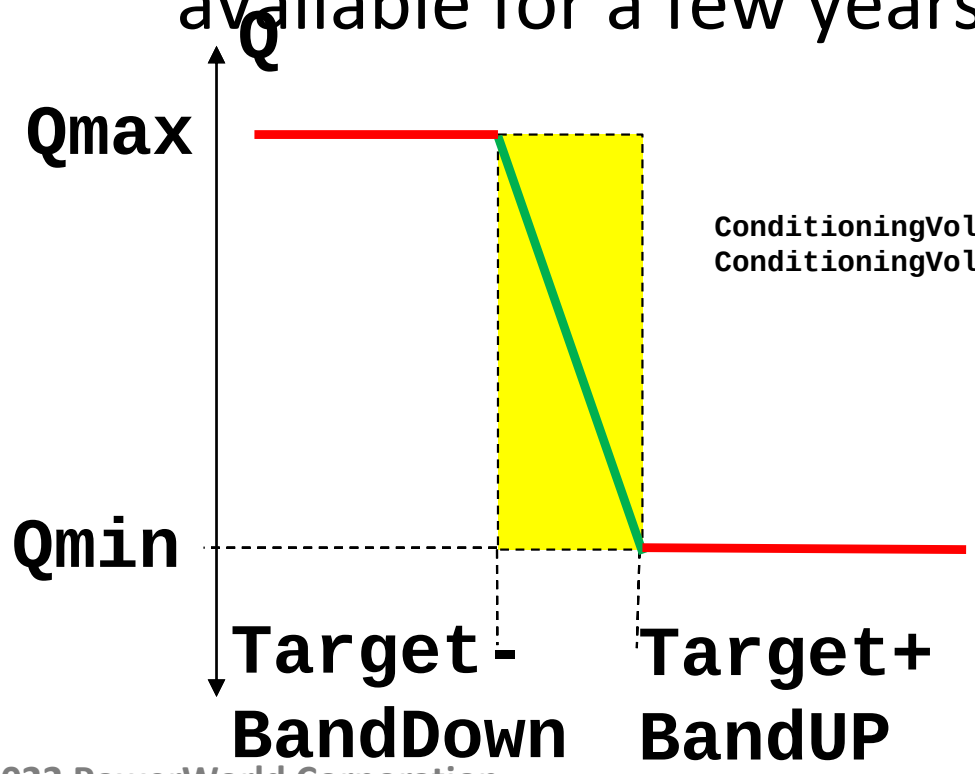
Target used with BandUp, BandDown

- BandUp, BandDown will be used to specify a voltage target range
  - Make use of the **Voltage Setpoint Tolerance** feature available for a few years in PowerWorld




```
ConditioningVoltSet      = (BandUpPU + BandDownPU)/2 + TargetPUA
ConditioningVoltSetTol   = (BandUpPU – BandDownPU)/2
```

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Voltage Equation is Replaced

- Presently a PV bus enforces the following equation

$$V_{reg} - V_{set} = 0$$

- To represent operation on the green line, this is replaced with the following line equation to create a "PVTol" bus instead of a PV bus.

$$V_{reg} - V_{set} + V_{tol} + \left(\frac{2V_{tol}}{Q_{min} - Q_{max}}\right)\left(-Q_{gen} + Q_{max}\right) = 0$$

- The red variables are functions of terminal voltage variables
  - Q_{gen} is the summation of generator Mvar outputs

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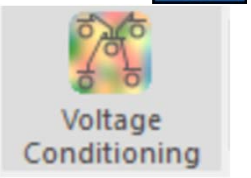
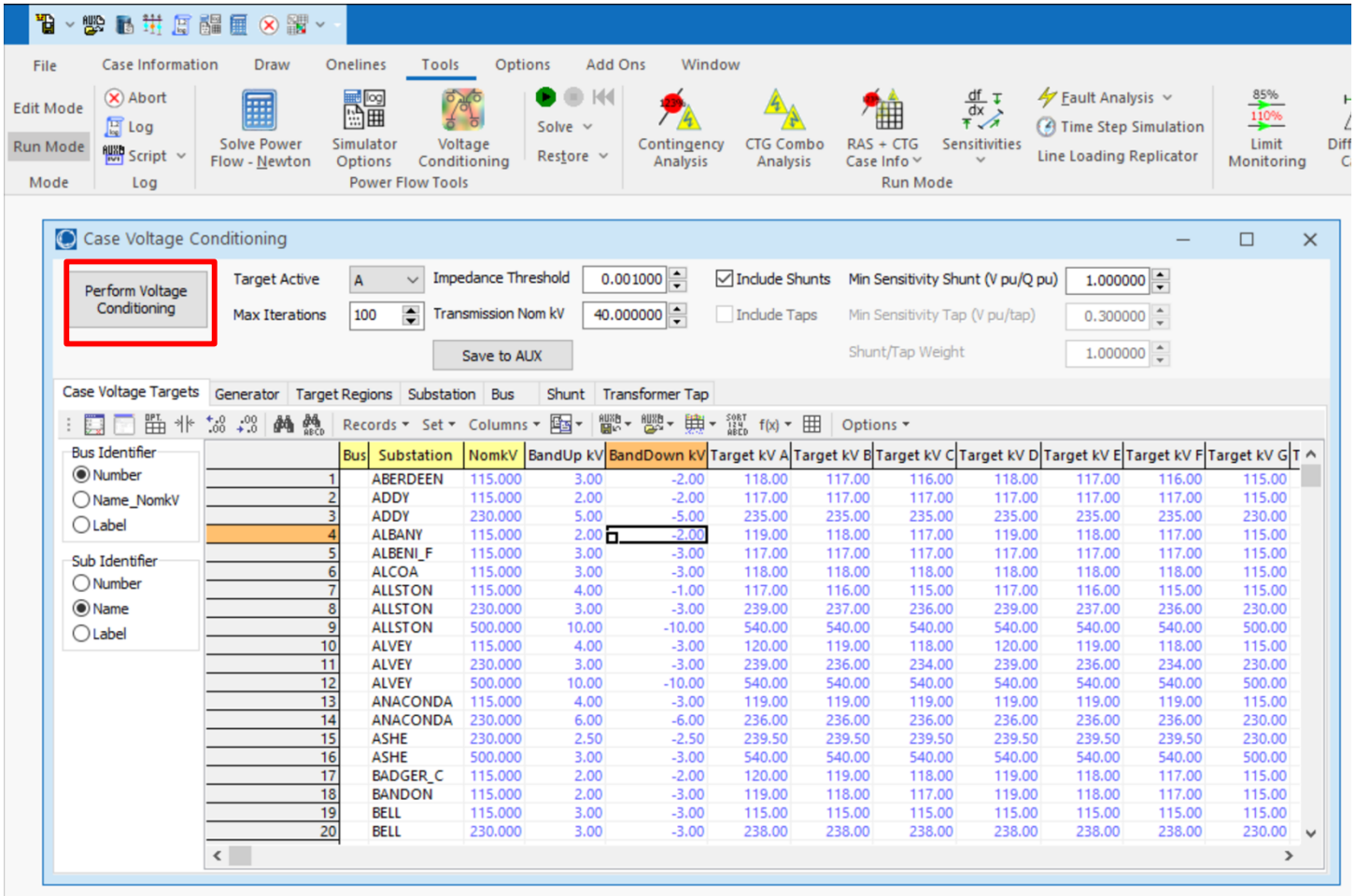
Perform Voltage Conditioning

- Available under Tools, Voltage Conditioning





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Perform Voltage Conditioning Process

1. Ensure that the existing case has an initial solved power flow solution
2. Iterate through all generators in the case to build a list that meet the following criteria
   a. `ConditioningAvailable` = YES.
   b. `ConditioningRegBus` is populated (this will be true for all buses with `Online` = NO)
   c. Using `ConditioningRegBus`, look up a `ConditioningVoltSet` from the table of CaseVoltageTarget objects. Only include generators that return a value for `ConditioningVoltSet`. Remember this will use the Bus object's
3. A list of generators meeting these requirements is built and then the following information is Cached before the process is begun
   a. `CACHE_RegBus = RegBus`
   b. `CACHE_AVR = AVR` (the `YES/NO` field)
   c. `CACHE_VoltSetTol = VoltSetTol`
4. With this cached, Simulator then runs through all the generators in the list and applies the following assignments to those.
   a. `RegBus = ConditioningRegBus`
   b. `AVR = YES`
   c. `VoltSet = ConditioningVoltSet`
   d. `VoltSetTol = ConditioningVoltSetTol`
5. A new power flow solution is solved which will use the voltage schedules and tolerances specified.
6. Using the final solved solution with the setpoints and tolerance, reset back to the original regulation settings (but with a new setpoint). Do this by setting the following
   a. `AVR = CACHE_AVR`
   b. `RegBus = CACHE_RegBus`
   c. `VoltSetTol = CACHE_VoltSetTol`
   d. Set `VoltSet` to match the new operating point.

   If a the `CACHE_VoltSetTol` is 0.0, then this just means `VoltSet = RegBus.Vpu`, Otherwise use the following logic

```
If      Mvar >= MvarMax Then VoltSet = RegBus.Vpu-VoltSetTol
else if Mvar <= MvarMin Then VoltSet = RegBus.Vpu+VoltSetTol
else                         VoltSet = RegBus.Vpu+VoltSetTol-2*VoltSetTol/(MvarMax-MvarMin)*(Mvar-MvarMin)
```

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Conclusion

- For now it moves the generator voltage setpoints around using the VoltageSetpointTolerance features
  - Returns back to a regulated bus without the tolerance though

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